Helios Prototype Spacecraft Deep Space Network Compatibility Test Summary

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The Helios Prototype Model Spacecraft/Deep Space Network (DSN) compatibility test program consisted of subsystem design, system design, and system verification tests in three phases, which were performed at the Jet Propulsion Laboratory and Cape Canaveral. Subsystem design tests were initiated on the Engineering Model in early 1972 and the program culminated in verification of DSN/Helios Spacecraft compatibility on Aug. 2, 1974. This report describes the tests and test results that provided the basis for establishment of telecommunications system design compatibility and verification.

I. Introduction

Phase I of the DSN/Helios Spacecraft Compatibility Test Program began at the Spacecraft Compatibility Station (formerly DSS 71) in April 1972. The Engineering Model (EM) transponder was tested extensively for RF, command, and metric compatibility, but telemetry testing was limited because of the nonavailability of the spacecraft data handling unit and DSN operational software. Several design deficiencies were discovered, principally interaction between the transmitter and receivers and interaction between the two receivers. Results of Phase I testing have been documented and are detailed in Ref. 1.

Phase II of the DSN/Helios Spacecraft Compatibility Test Program was performed with the Compatibility Test Area (CTA 21) in May 1974. CTA 21 is the DSN facility established to simulate an operational Deep Space

Station for verification of communications performance. The objectives of this series of tests was to establish system design compatibility between the Prototype Model (PM) Spacecraft and the DSN.

Phase III of the test program was performed at Cape Canaveral, Florida, between the DSN equipment at the Goddard Tracking Station at Merritt Island, Florida and the Helios PM. The DSN equipment is referred to as STDN (MIL 71). The objectives of these tests were twofold: (1) to verify continued interface integrity and maintenance of compatibility following transportation of the PM Spacecraft to Florida, and (2) to verify the capability of STDN (MIL 71) to support Flight Project/DSN compatibility testing.

Procedures for conducting these tests were prepared by the DSN and included DSN test parameters and criteria. Spacecraft test parameters and design criteria were provided by the Helios Telecommunications Project of the German Society for Space Research (GfW). The final procedures were approved by a joint DSN/Helios Project test team.

II. Test Report

Initial testing with the Engineering Model Transponder at DSS 71 in April 1972 uncovered several design incompatibilities between the transponder and the DSN. The transponder exhibited lag in sensitivity, pushing effects at strong uplink signal levels, instability of the voltage-controlled crystal oscillator (VCXO) and improper shielding. Despite these incompatibilities, meaningful engineering tests were performed as documented in Ref. 1. The last two phases of the DSN/Helios Spacecraft Compatibility Test Program were successful in establishing telecommunications compatibility between the DSN and the Helios Prototype Spacecraft.

A. Prototype CTA 21 Testing

1. Test objectives. The objectives of these tests were to prove system design compatibility between the DSN and the PM spacecraft and to demonstrate that compatibility deficiencies in the EM had been resolved. All tests were accomplished in accordance with the DSN test/training plan described in Ref. 2.

2. Test conditions. The Helios Prototype Spacecraft was located in Building 248 (10-ft solar simulator) and an RF link was established to CTA 21 in Building 125 at JPL. CTA 21 was configured as a standard DSS utilizing operational hardware and software including Telemetry and Command Processor (TCP) software, DOI-5050 (OP-B, modified). The Helios spacecraft was configured for flight operation.

On May 17, the RF link was tested and the amplitude stability was measured to be ± 0.2 dB over a 24-hour period. The formal tests started on May 18 and the test duration was approximately 120 hours. Excellent support from the spacecraft team and CTA 21 provided a smooth and continuous flow of testing. Decommutation of spacecraft telemetry via high-speed data blocks to the Simulation Conversion Assembly (SCA) provided real-time spacecraft operating parameters, such as receiver automatic gain control (AGC) and receiver static phase error, (SPE). This configuration performance of the DSN Telemetry System through the DSN Ground Communications Facility (GCF) High-Speed Data Subsystem.

3. Test results. Table 1 provides in summary form the test results. Significant events and/or items in the areas of RF telemetry, command and metric data are described below:

a. Radio frequency. The standard DSN RF tests of tracking range, rate and acquisition under doppler conditions were very successful. In particular, very limited pushing or pulling effects were noted over a range of plus and minus 32.5 kHz in the spacecraft transponder. All RF thresholds corresponded to predicted values and were very stable. The redesign of the Helios transponder was successful.

b. Command. Station-to-spacecraft command operation performance for DSN-generated commands was successfully tested at threshold levels, for a total of 1500 commands with and without ranging and under simulated mission conditions (i.e., under spacecraft low-gain antenna amplitude and phase variations in the uplink).

The mission critical command performance during the Step II maneuver was successfully verified.

c. Metric data. A series of tests was performed utilizing the Planetary Ranging Assembly (PRA) for both the continuous and discrete modes. In addition, verification of the PRA and the Mark I A range delay measurements through the spacecraft was performed. The difference between the two ranging systems' measurements was approximately 2 ns.

The acquisition times, spacecraft range delay at simulated 1.6 and 2.0 AU conditions, range stability, and DRVID stability tests were performed with the spacecraft at ambient temperatures.

No interference between ranging, command, and telemetry was observed with the discrete mode of ranging. In particular, an 8-hour DRVID test indicated a very stable spacecraft transponder. The variation of the DRVID number due to the transponder was measured to be less than 5 ns.

d. Telemetry. The telemetry tests were designed to verify both coded and uncoded telemetry performance of the DSN with the Helios spacecraft. Uncoded telemetry performance was tested by determining the bit error rate (utilizing test software DOI-5087-TP) and decommutating HSD blocks. Coded telemetry performance was verified by measuring the frame deletion rate for 8, 256, and 2048 bps, and a review of the HSD block integrity was made. Both the coded and uncoded telemetry performance met the test criteria of bit error and frame deletion rate, with the exception of bit error tests performed at 8 bps and 32 bps uncoded. The 8 and 32 bps uncoded modes are not critical to the Helios mission; however, tests with the Helios PTM spacecraft were planned with STDN (MIL-71) to provide operational performance estimates at these rates.

The 128-bps uncoded tests (critical for Step II maneuver) were successfully performed.

B. Prototype Spacecraft/STDN (MIL 71) Testing

1. Test objectives. The objectives of the tests were to verify design compatibility between the DSN and the Helios Prototype Spacecraft after transportation from JPL and to provide training in preparation for compatibility tests with the flight article at Cape Canaveral, Florida. All tests were accomplished in accordance with the DSN Test/Training Plan for Helios Project, 613-4; Rev. A.

2. Test conditions. The Helios Prototype Spacecraft was configured to represent a flight model and STDN (MIL 71) was configured to represent a 26-meter antenna DSS. The spacecraft was located in the clean room of Building AO, Cape Canaveral, Florida. An S-band RF air link was established between a 1.85-meter antenna at Building AO and a 1.2-meter antenna at the ground station.

The ground station telemetry and command software utilized in these tests was the released version of Telemetry and Command Data (TCD) DOI-5050-OP-C. This package is the final revision of station operational software which will be used to support the Helios mission. Bit error rate testing was supported utilizing the multiple-mission telemetry (MMT) test software, DOI-5087-TP. The total time to accomplish the Helios Prototype Spacecraft/STDN (MIL 71) compatibility tests was 39 hours. The test schedule was on the basis of a 12-hour shift. The successful accomplishment of the RF compatibility tests was due in large measure to the outstanding cooperation and coordination between the Helios Project Spacecraft test team and the STDN (MIL 71) Team.

3. Test results. Table 2 provides in summary form the test results. Significant events and/or items in the areas of RF, telemetry, command and metric data are described below:

a. Radio frequency. Short-term RF link fluctuations throughout the test period were observed and recorded to be $\pm$ 4.0 dB on the downlink and $\pm$ 3.0 dB on the uplink. These fluctuations were primarily caused by a faulty three-way directional coupler used for test purposes at the spacecraft antenna inputs. Elimination of this coupler reduced link fluctuations to $\pm$ 1.5 dB on the downlink and $\pm$ 1.5 dB on the uplink.

No observable degradation to downlink and uplink threshold performance was observed despite link fluctuations. All RF acquisition and tracking rate tests were well within the expected tolerances.

The subcarrier phase jitter measurement at STDN (MIL 71) was significantly improved over the same measurement performed at CTA 21. The measurement at CTA 21 (8 deg rms) is assumed to be due to an error in CTA 21 test instrumentation.

b. Commands. Command performance testing was attempted five times and was successfully accomplished after a noisy directional coupler at the spacecraft complex was replaced toward the end of the test period. Experience with the noisy uplink revealed that the actual command threshold of the spacecraft was approximately 3 dB below the specified value of -144 dBm.

c. Metric. All metric data testing proceeded flawlessly. Both discrete and continuous ranging delay measurements were as expected.

d. Telemetry. All telemetry erasure rate tests for the coded telemetry were performed as expected. All test criteria were met or exceeded.

Bit error rate measurements for the uncoded mode of operations were slightly outside the expected limits. This deviation from the May 1974 test results at CTA 21 was attributable to the unstable RF link performance observed during these tests.

The 8 and 32 bps uncoded performance problems described previously in the Prototype Spacecraft/CTA 21 testing were not observed. With the exception of the RF link stability problem, the 8 and 32 bps uncoded telemetry performed flawlessly.

III. Conclusions

The successful completion of Helios Spacecraft telecommunications test activities at Pasadena and Cape Canaveral represents a significant project event. It can be assumed with high probability that the telecommunications design compatibility established with the PM will also be established with the Helios Flight (F-1) Spacecraft.

The importance of the performance of a formal compatibility test program is clearly demonstrated by the problem areas uncovered, verified and resolved during the DSN/Helios Prototype Spacecraft Test Program.

References

1. *DSN Test/Training Plan for Helios Project; Vol. III, Part A, DSN/Helios Spacecraft Telecommunications Compatibility Test Report*, Document 613-8, July 1, 1972 (JPL internal document).
2. *DSN/Test Training Plan for Helios Project, Vol. I, Part A, DSN/Helios Spacecraft Telecommunications Compatibility Test Plan*, Document 613-4; Rev. A, June 15, 1973 (JPL internal document).
3. *DSN Test/Training Plan for Helios Project, Vol. II, Part A, DSN/Helios Spacecraft Telecommunications Compatibility Test Procedures*, Document 613-5, June 15, 1972 (JPL internal document).
4. *Deep Space Network/Helios Spacecraft Telecommunications Interface Definition*, Document 613-6; Rev. A, Feb. 1, 1974 (JPL internal document).

Test date	Test title	Test No.	Deep Space Network										
			BLK III RCV	BLK III EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate	EXC
5-18-74	S/C maximum sweep and acquisition rate	I.1	1	1	Off	Off	500 Hz/sec	−30.0 kHz	NA	NA	High	2048	1
		I.1	1	1	Off	Off	500 Hz/sec	+30.0 kHz	NA	NA	High	2048	1
		I.2	1	1	Off	Off	80 Hz/sec	−10.0 kHz	NA	NA	High	2048	1
		I.2	1	1	Off	Off	80 Hz/sec	+10.0 kHz	NA	NA	High	2048	1
		I.3	1	1	Off	Off	500 Hz/sec	−30.0 kHz	NA	NA	High	2048	1
		I.3	1	1	Off	Off	500 Hz/sec	+30.0 kHz	NA	NA	High	2048	1
		I.4	1	1	Off	Off	80 Hz/sec	−10.0 kHz	NA	NA	High	2048	1
		I.4	1	1	Off	Off	80 Hz/sec	+10.0 kHz	NA	NA	High	2048	1
5-17-74	Noncoherent downlink spectrum analysis	II.1	1	NA	Off	Off	NA	NA	NA	NA	Low	32	1
		II.2	1	NA	Off	Off	NA	NA	NA	NA	High	2048	1
		II.3	1	NA	Off	Off	NA	NA	NA	NA	Low	32	1
5-18-74	Noncoherent downlink spectrum analysis	II.4	1	NA	Off	Off	NA	NA	NA	NA	High	2048	1
		II.5	1	NA	Off	Off	NA	NA	NA	NA	High	128	1
5-18-74	Coherent downlink spectrum analysis	II.6	1	1	Off	Idle on	NA	NA	NA	NA	Low	32	1
		II.7	1	1	Off	Idle on	NA	NA	NA	NA	Low	32	1
		II.8	1	1	Off	Idle on	NA	NA	NA	NA	High	2048	1

Table 1. Helios Prototype Spacecraft telecommunications compatibility test data from CTA 21

Spacecraft						Test data		Test time	Test comment
RCV	ANT (PWR)	TWT	RNG	S/C DM	S/C FM	Performance	Criteria		
1 & 2 (VCX01)	MGA (High)	1	Off	0	4	Acquired @ −100.0 dBmW; Tracked to +32.5 kHz	Acquire @ −100.0 dBmW; Track to +32.5 kHz	1 hr 15 min	Acquired U/O @ best lock (VCX01) 2115.699552 MHz
1 & 2 (VCX01)	MGA (High)	1	Off	0	4	Acquired @ −100.0 dBmW; Tracked to −32.5 kHz	Acquire @ −100.0 dBmW; Track to −32.5 kHz		Acquired U/L @ best lock (VCX01) 2115.699552 MHz
1 & 2 (VCX01)	MGA (High)	1	Off	0	4	Acquired @ −141.0 dBmW; Tracked to +32.5 kHz	Acquire @ −141.0 dBmW; Track to +32.5 kHz		Acquired U/L @ best lock (VCX01) 2115.699552 MHz
1 & 2 (VCX01)	MGA (High)	1	Off	0	4	Acquired @ −141.0 dBmW; Tracked to −32.5 kHz	Acquire @ −141.0 dBmW; Track to −32.5 kHz		Acquired U/L @ best lock (VCX01) 2115.699552 MHz
1 & 2 (VCX02)	MGA (High)	1	Off	0	4	Acquired @ −100.0 dBmW; Tracked to +32.5 kHz	Acquire @ −100.0 dBmW; Track to +32.5 kHz	0 hr 45 min	Acquired U/L @ best lock (VCX02) 2115.697344 MHz
1 & 2 (VCX02)	MGA (High)	1	Off	0	4	Acquired @ −100.0 dBmW; Tracked to −32.5 kHz	Acquire @ −100.0 dBmW; Track to −32.5 kHz		Acquired U/L @ best lock (VCX02) 2115.697344 MHz
1 & 2 (VCX02)	MGA (High)	1	Off	0	4	Acquired @ −141.0 dBmW; Tracked to +32.5 kHz	Acquire @ −141.0 dBmW; Track to +32.5 kHz		Acquired U/L @ best lock (VCX02) 2115.697344 MHz
1 & 2 (VCX02)	MGA (High)	1	Off	0	4	Acquired @ −141.0 dBmW; Tracked to −32.5 kHz	Acquire @ −141.0 dBmW; Track to −32.5 kHz		Acquired U/L @ best lock (VCX02) 2115.697344 MHz
1	MGA (Med)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	53 min	
1	MGA (Med)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	6 min	
1	MGA (High)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	10 min	
1	MGA (High)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	7 min	
1	LGA (Low)	NA	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	11 min	
1	MGA (Med)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	28 min	U/L level −144 dBmW
1	MGA (High)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	14 min	U/L level −144 dBmW
1	HGA (High)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	19 min	U/L level −103 dBmW

Test date	Test title	Test No.	Deep Space Network										
			BLK III RCV	BLK III EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate	EXC
5-18-74	Coherent downlink spectrum analysis (contd)	II.9	1	1	Off	Idle on	NA	NA	NA	NA	High	2048	1
		II.10	1	1	Off	Idle on	NA	NA	NA	NA	High	2048	1
5-18-74	Uplink threshold	III.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
5-20-74	Residual carrier phase jitter	IV.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
			1	1	Off	On	NA	NA	NA	NA	High	2048	1
		IV.2	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
			1	1	Off	On	NA	NA	NA	NA	High	2048	1
		IV.3	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
5-20-74	Residual carrier phase jitter	IV.4	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.5	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.6	1	1	Off	Off	NA	NA	NA	NA	Off	Off	1
			1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.7	1	1	Off	Off	NA	NA	NA	NA	Off	Off	1
			1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.8	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.9	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
5-20-74	Noncoherent downlink threshold	V.1	1	1	NA	NA	NA	NA	NA	NA	Low	32	1
		V.2	1	1	NA	NA	NA	NA	NA	NA	High	2048	1
5-20-74	Coherent downlink threshold	V.3	1	1	Off	Off	NA	NA	NA	NA	Low	32	1
		V.4	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		V.5	1	1	On	Off	NA	NA	NA	NA	High	2048	1
		V.6	1	1	On	Off	NA	NA	NA	NA	Low	32	1
5-20-74	S/C ranging polarity	VI.1	1	1	On	Off	NA	NA	NA	NA	High	2048	1

Table 1 (contd)

Spacecraft						Test data		Test time	Test comment
RCV	ANT (PWR)	TWT	RNG	S/C DM	S/C FM	Performance	Criteria		
1	HGA (Med)	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	25 min	U/L level −144 dBmW
1	HGA (High)	1	On	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	1 hr 42 min	U/L level −132.5 dBmW
1	MGA (High)	1	Off	0	4	−154.35 dBmW	−155.0 ± 1.0 dBmW	45 min	Average of three measurements
1	MGA (Med)	1	Off	0	4	5.7 deg rms	2.86 deg rms	3 hr 26 min	U/L level −100 dBmW
1	MGA (Med)	1	Off	0	4	6.2 deg rms	↓	↓	D/L level −100 dBmW
1	MGA (Med)	1	Off	0	4	17.98 deg rms	22.9 deg rms	↓	U/L level −144 dBmW
1	MGA (Med)	1	Off	0	4	18.1 deg rms	↓	↓	D/L level −100 dBmW
1	MGA (High)	1	Off	0	4	5.23 deg rms	2.86 deg rms	↓	U/L level −100 dBmW D/L level −100 dBmW
1	MGA (High)	1	Off	0	4	17.29 deg rms	22.9 deg rms	3 hr 26 min	U/L level −144 dBmW D/L level −100 dBmW
1	MGA (High)	1	Off	0	4	1.78 deg rms	5.7 deg rms	↓	D/L level −100 dBmW Noncoherent mode
1	MGA (Med)	1	Off	0	4	0.78 deg rms	5.7 deg rms	↓	TLM modulation Off Noncoherent mode
1	MGA (Med)	1	Off	0	4	1.66 deg rms	↓	↓	D/L level −100 dBmW Noncoherent mode
1	LGA (Low)	NA	Off	0	4	4.96 deg rms	2.86 deg rms	↓	TLM modulation Off Coherent mode
1	LGA (Low)	NA	Off	0	4	5.12 deg rms	↓	↓	U/L level −100 dBmW D/L level −100 dBmW
1	LGA (Low)	NA	Off	0	4	16.77 deg rms	22.9 deg rms	↓	U/L level −144 dBmW D/L level −100 dBmW
1	LGA (Low)	NA	Off	0	4	1.65 deg rms	5.7 deg rms	↓	D/L level −100 dBmW Noncoherent mode
1	HGA (High)	1	Off	0	4	−159.7 dBmW	−159.0 ± 3.0 dBmW	20 min	Avg. three runs
1	HGA (High)	1	Off	0	4	−158.8 dBmW	−159.0 ± 3.0 dBmW	14 min	Avg. three runs
1	MGA (High)	1	Off	0	4	−161.8 dBmW	−159.0 ± 3.0 dBmW	13 min	Avg. three runs
1	MGA (High)	1	Off	0	4	−158.5 dBmW	−159.0 ± 3.0 dBmW	13 min	Avg. three runs
1	MGA (High)	1	On	0	4	−157.8 dBmW	−159.0 ± 3.0 dBmW	18 min	Continuous spectrum Avg. three runs
1	MGA (High)	1	On	0	4	−160.6 dBmW	−159.0 ± 3.0 dBmW	13 min	Discrete spectrum Avg. three runs
1	HGA (High)	1	On	0	4	Not inverted	Polarity not inverted	15 min	Continuous spectrum

Test date	Test title	Test No.	Deep Space Network										
			BLK III RCV	BLK III EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate	EXC
5-20-74	S/C ranging delay	VI.2	1	1	On	Off	NA	NA	NA	NA	High	2048	1
		VI.3	1	1	On	Off	NA	NA	NA	NA	High	2048	1
5-21-74	Ranging system acquisition time	VII.1	1	1	On	Off	NA	NA	NA	NA	High	2048	1
		VII.2	1	1	On	Off	NA	NA	NA	NA	Low	32	1
5-21-74	Bit error rate	VIII.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		VIII.2	1	1	Off	Off	NA	NA	NA	NA	High	64	1
		VIII.3	1	1	Off	Off	NA	NA	NA	NA	Low	32	1
		VIII.4	1	1	Off	Off	NA	NA	NA	NA	Low	8 UNC	1
		VIII.5	1	1	On	Off	NA	NA	NA	NA	High	2048	1
		VIII.6	1	1	Off	Off	NA	NA	NA	NA	High	128	1
5-23-74	Telemetry erasure rate	IX.1	1	1	Off	On	NA	NA	NA	NA	High	2048	1
		IX.1a	1	1	Off	On	NA	NA	NA	NA	High	2048	1
		IX.2	1	1	Off	On	NA	NA	NA	NA	High	256	1
		IX.3	1	1	On	On	NA	NA	NA	NA	High	2048	1
		IX.4	1	1	Off	On	NA	NA	NA	NA	High	128	1
		IX.7	1	1	On	On	NA	NA	NA	NA	Low	8	1
		IX.8	1	1	On	On	NA	NA	NA	NA	High	2048	1
5-18-74	Subcarrier frequency and phase jitter	X.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
5-22-74	Spacecraft command threshold	XI.1	1	1	Off	On	0	0	0	NA	High	2048	1
		XI.2	1	1	On	On	0	0	0	NA	High	2048	1

Table 1 (contd)

Spacecraft						Test data		Test time	Test comment
RCV	ANT (PWR)	TWT	RNG	S/C DM	S/C FM	Performance	Criteria		
1	HGA (High)	1	On	0	4	1409 ns	To be measured	33 min	Continuous spectrum
1	HGA (High)	1	On	0	4	1407 ns	To be measured	22 min	Discrete spectrum
1	HGA (High)	1	On	0	4	23 min	Less than 45 min 1.6 AU case	1 hr 30 min	Continuous spectrum U/L level −133.0 dBmW D/L level −132.1 dBmW
1	HGA (High)	1	On	0	4	1.8 min	Less than 0.8 min 2.0 AU case	29 min	Discrete spectrum U/L level −134.5 dBmW D/L level −135.0 dBmW
1	MGA (Med)	1	Off	0	4	2.1×10^{-5}	10^{-5}	10 min	D/L level −128.2 dBmW
1	MGA (Med)	1	Off	0	4	0	10^{-4}	57 min	D/L level −140.8 dBmW
1	MGA (Med)	1	Off	0	4	1.5×10^{-6}	10^{-4}	2 hr 7 min	D/L level −141.7 dBmW
1	MGA (Med)	1	Off	0	4	No results	10^{-3}	4 hr 12 min	D/L level −147.7 dBmW
1	MGA (Med)	1	On	0	4	3.1×10^{-5}	10^{-5}	17 min	Discrete spectrum D/L level −128.2 dBmW
1	MGA (Med)	1	Off	0	4	3.55×10^{-5}	10^{-3}	25 min	D/L level −138.4 dBmW
1	MGA (Med)	1	Off	0	4	2.1×10^{-4}	10^{-4}	1 hr 30 min	D/L level −131.8 dBmW
1	MGA (Med)	1	Off	0	4	1.9×10^{-2}	$>10^{-1}$	1 hr	D/L level −134.9 dBmW
1	MGA (Med)	1	Off	0	4	0	10^{-4}	7 hr	D/L level −139.3 dBmW
1	MGA (Med)	1	On	0	4	0	10^{-4}	2 hr	D/L level −131.5 dBmW
1	MGA (Med)	1	Off	0	4	0	10^{-3}	2 hr	D/L level −132.1 dBmW
1	MGA (Med)	1	On	0	4	0	Process 200 frames	7 hr 30 min	D/L level −153.3 dBmW
1	MGA (Med)	1	On	0	4	0	Process 3200 frames	11 hr 30 min	D/L level −142.0 dBmW
1	MGA (Med)	1	Off	0	4	32.768 kHz @ 8.0 deg rms	32.768 kHz To be measured	1 hr 38 min	
1	MGA (High)	1	Off	0	4	1.3×10^{-5}	10^{-5}	8 hr 15 min	512-Hz subcarrier
1	MGA (High)	1	On	0	4	0	10^{-5}	32 min	512-Hz subcarrier, discrete spectrum

Test date	Test title	Test No.	Deep Space Network										
			BLK III RCV	BLK III EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate	EXC
5-23-74	Command bit error rate with uplink spin modulation	XII.1	1	1	Off	On	Freq. modulation: ±35 Hz @ 1 Hz/sec Phase modulation: ±40 deg @ 20 Hz/sec Amp. modulation: 10 dB p-p @ 20 Hz/sec		None	NA	High	128	1
		XII.2	1	1	Off	On	Phase modulation: ±40 deg @ 20 Hz/sec Amp. modulation: 16 dB p-p @ 20 Hz/sec		None	NA	High	128	1
6-1-74	Differenced ranging versus integrated doppler (DRVID)	XIII.1	1	1	On	Off	0	0	NA	NA	High	2048	1

Table 1 (contd)

Spacecraft						Test data		Test time	Test comment
RCV	ANT (PWR)	TWT	RNG	S/C DM	S/C FM	Performance	Criteria		
1	MGA (High)	1	Off	0	4	0	10^{-5}	1 hr	U/L level −128 dBmW
1	MGA (High)	1	Off	0	4	0	10^{-1}	30 min	U/L level −114 dBmW
1	MGA (High)	1	On	0	4	3 ns drift	<5-ns drift	8 hr	U/L level −100 dBmW D/L level −113 dBmW

Test date	Test title	Test No.	Deep Space Network										
			BLK III RCV	BLK III EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate	EXC
7-31-74	S/C maximum sweep and acquisition rate	I.1	1	1	Off	Off	500 Hz/sec	−30.0 kHz	NA	NA	High	2048	1
		I.1	1	1	Off	Off	500 Hz/sec	+30.0 kHz	NA	NA	High	2048	1
		I.2	1	1	Off	Off	80 Hz/sec	−10.0 kHz	NA	NA	High	2048	1
		I.2	1	1	Off	Off	80 Hz/sec	+10.0 kHz	NA	NA	High	2048	1
7-31-74	Downlink spectrum analysis	II.1	1	NA	Off	Off	NA	NA	NA	NA	High	128	1
		II.2	1	NA	Off	Off	NA	NA	NA	NA	High	2048	1
		II.3	1	1	Off	On	NA	NA	NA	NA	High	2048	1
		II.4	1	1	Off	On	NA	NA	NA	NA	Low	32	1
7-31-74	Uplink threshold	III.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
7-31-74	Carrier residual phase jitter	IV.3	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.4	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IV.5	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
7-31-74	Coherent downlink threshold	V.5	1	1	On	Off	NA	NA	NA	NA	High	2048	1
7-31-74	S/C ranging polarity and delay	VI.2	1	1	On	Off	NA	NA	NA	NA	High	2048	1
		VI.3	1	1	On	Off	NA	NA	NA	NA	High	2048	1
8-2-74	Bit error rate	VIII.3	1	1	Off	Off	NA	NA	NA	NA	Low	32 Uncoded	1
		VIII.4	1	1	Off	Off	NA	NA	NA	NA	Low	8 Uncoded	1
8-1-74	Telemetry erasure rate	IX.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
		IX.2	1	1	Off	Off	NA	NA	NA	NA	High	256	1
		IX.8	1	1	Off	Off	NA	NA	NA	NA	High	128	1
8-2-74	Subcarrier frequency and phase jitter	X.1	1	1	Off	Off	NA	NA	NA	NA	High	2048	1
8-2-74	Spacecraft command threshold	XI.1	1	1	Off	On	NA	NA	NA	NA	High	2048	1

Table 2. Helios Prototype Spacecraft telecommunications compatibility test data from STDN/MIL-17

Spacecraft							Test data		Test time	Test comment
RCV	PWR	ANT	TWT	RNG	S/C DM	S/C FM	Performance	Criteria		
1 & 2	High	MGA	1	Off	0	4	Acquire @ −100 dBmW; tracked to +32.5 kHz	Acquire @ −100 dBmW; track to +32.5 kHz	2 hr 43 min	Acquire U/L @ best lock 2115.705024 MHz
1 & 2	High	MGA	1	Off	0	4	Acquired @ −100 dBmW; tracked to −32.5 kHz	Acquire @ −100 dBmW; track to −32.5 kHz		Acquired U/L @ best lock 2115.705024 MHz
1 & 2	High	MGA	1	Off	0	4	Acquired @ −141 dBmW; tracked to +32.5 kHz	Acquire @ −141 dBmW; track to +32.5 kHz		Acquired U/L @ best lock 2115.705024 MHz
1 & 2	High	MGA	1	Off	0	4	Acquired @ −141 dBmW; track to −32.5 kHz	Acquire @ −141 dBmW; track to −32.5 kHz		Acquired U/L @ best lock 2115.705024 MHz
1	Med	MGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	48 min	
1	High	MGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	9 min	
1	High	MGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	17 min	
1	Med	MGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	17 min	
1	High	MGA	1	Off	0	4	−154.3 dBmW	−155.0 ± 1.0 dBmW	1 hr 16 min	
1	High	MGA	1	Off	0	4	1.74 deg rms	To be measured	58 min	U/L level −100.0 dBmW
1	High	MGA	1	Off	0	4	18.67 deg rms	To be measured		U/L level −144.0 dBmW
1	High	MGA	1	Off	0	4	1.55 deg rms	To be measured		Spacecraft in noncoherent mode
1	High	MGA	1	On	0	4	−159.5 dBmW	−159.0 ± 3.0 dBmW	1 hr 1 min	
1	High	HGA	1	On	0	4	1410.8 ns	To be measured	33 min	Polarity not inverted, continuous spectrum
1	High	HGA	1	On	0	4	1389.3 ns	To be measured		polarity not inverted, discrete spectrum
1	Med	MGA	1	Off	0	4	4.3×10^{-4}	10^{-4}	2 hr 47 min	8 dB Peak-to-peak RF link variation
1	Med	MGA	1	Off	0	4	1.6×10^{-3}	10^{-3}	3 hr 31 min	8 dB Peak-to-peak RF link variation
1	Med	MGA	1	Off	0	4	0.0%	0.01%	3 hr 10 min	10^4 Frames
1	Med	MGA	1	Off	0	4	0.0%	0.01%	1 hr 25 min	2×10^3 Frames
1	High	HGA	1	On	0	4	0.06%	0.1%	4 hr 33 min	1.6×10^3 Frames
1	Med	MGA	1	Off	0	4	32.768 kHz @ 0.38 deg rms	32.768 kHz To be measured	16 min	
1	High	MGA	1	Off	0	4	Ground station transmitted 120 commands, all confirmed at spacecraft	Spacecraft receive all commands	1 hr	U/L level −144.0 dBmW

Table 3. Definitions for Tables 1 and 2

BLK III receiver	The standard DSN S-band receiving equipment
BLK III exciter	The standard DSN S-band exciter equipment
PRA RNG	Planetary ranging assembly modulation
CMD	Telemetry and command data handling command modulation
Uplink doppler	Ramp rate of the uplink carrier frequency
Uplink offset	Uplink carrier frequency offset relative to the spacecraft receiver rest frequency
CMA SUBC offset	Command modulation assembly subcarrier frequency offset relative to nominal
SDA SUBC offset	Subcarrier demodulator assembly subcarrier frequency offset relative to nominal
CAR SUP	Downlink carrier suppression due to telemetry modulation
Bit rate	Clock frequency of the telemetry bit information
EXC	Spacecraft S-band exciter equipment
RCV	Spacecraft S-band receiving equipment
PWR	Spacecraft transmitter power mode
ANT	Spacecraft antenna
LGA	Low-gain antenna
MGA	Medium-gain antenna
HGA	High-gain antenna
TWT	Traveling wave tube amplifier
RNG	Spacecraft ranging channel
S/C DM	Spacecraft data mode
S/C FM	Spacecraft data format